Technical Bulletin: Advantages of using the Film Properties Predictor

1 Introduction

The tubular film extrusion process is one of the most used polymer transformation techniques worldwide. It has great relevance in the packaging production of several products in food and medicinal industry, where LLDPE and LDPE are the most used materials.

Packaging manufacturers always want to increase their products' profitability, that is to say, maximize mechanical properties and appearance of films with the lowest possible production costs. One way to achieve these goals is to use blends of two or more polymers, which allow satisfying specifics needs, looking for a balance between the inherent advantages of each blend component and transformation process variables that influence the final product properties.

The available quantity of raw materials for flexible packaging production is varied. In Venezuela, it is possible to select from more than 9 Venelene® polyethylene resins to obtain an appropriate balance in the final properties of product. Also, if it is considered the possibility of adding other resins or additives to modify certain characteristics, film producers are faced with the dilemma of knowing if their blends or transformation processes are the most suitable or optimal for their application. In addition, as usual in any industrial process, getting the optimal processing conditions to meet the application specific requirements always involves losses of raw material and hours of work, and therefore, impacts on costs.

The main purpose of this technical bulletin is to show the reader the advantages of the Film Properties Predictor (FPP) that POLINTER has developed for its clients, in order to facilitate the task of selecting the best combination of materials and processing conditions for the application in development.

The Film Properties Predictor is a software developed to allow the user introduce characteristics of the resins that are going to be blended (type and quantity) and their processing conditions; and as a result obtain predictions of the final film properties, using numerical methodology of neural networks with historical data from studies carried out in the INDESCA laboratories. With this tool any producer can reduce testing time in production plant (with the consequent saving of materials and hours of work) and to experience the possibilities of developing new applications or improving their existing products.

2 How is a blend designed?

Before presenting the benefits and how easy is to use the Film Properties Predictor, it is important to highlight the steps that must be followed when a blend is designed, either formally or intuitively and almost unconsciously. A formal and documented sequence allows achieving optimizations from the beginning, which will provide savings and/or better product performances.

The following list proposes a series of steps that should be considered when a polymer blend is designed:

1. Define quantitatively the desired blend properties. The Film Properties Predictor will allow you to quantify the blend quality using the numerical values of properties obtained from it.
2. Select resins with potential to achieve the goals, according to the desired properties, including their costs.
3. Tabulate the advantages and disadvantages of each resin. This will enable to identify alternatives.
4. Use the tool to evaluate combinations of resins that show some potential to meet blend requirements.
5. Make a first estimate of costs. If they are attractive, go ahead; otherwise, select another set of resins (step 4).
6. Analyze the selected blend from a point of view which considers processing conditions and final applications requirements. There are certain aspects, such as appearance, that cannot be assessed with the Film Properties Predictor.

- Is it obvious that it will work or is it obvious otherwise?
- Will it be possible to fabricate with the available equipment?
- Will it retain its properties throughout its useful life?

7. If the select blend is considered appropriate, use the tool to estimate the film properties. Compare against the desired properties (step 1) and adjust the thickness, blend component concentrations or processing conditions to optimize the final properties of the film.

3 Use of the Film Properties Predictor

This tool is available on the POLINTER website, which makes it accessible to all its clients, both nationally and internationally. Users must select the button shown in Figure 1, which is in the technical information section of the Venelene® grades for film fabrication.

Figure 1: Button to access the Film Properties Predictor

Once this link is selected, the Home page of the Film Properties Predictor is displayed in a new browser tab (see Figure 2) where it is found options for knowing the instructions of use, the main definitions of the terminology and the "Calcular" button, which is used to access the section where predictions of film properties are made.

Figure 2: Home page of the Film Properties Predictor.

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In the page displayed after selecting "Calcular" button, the user can specify in a graphic and simple way the processing conditions and materials that will use to manufacture the film (see Figure 3).

The materials and processing conditions are divided in four sections (Hopper, Bubble, Extruder and Die Head), which have default values that can be modified according to the user needs.

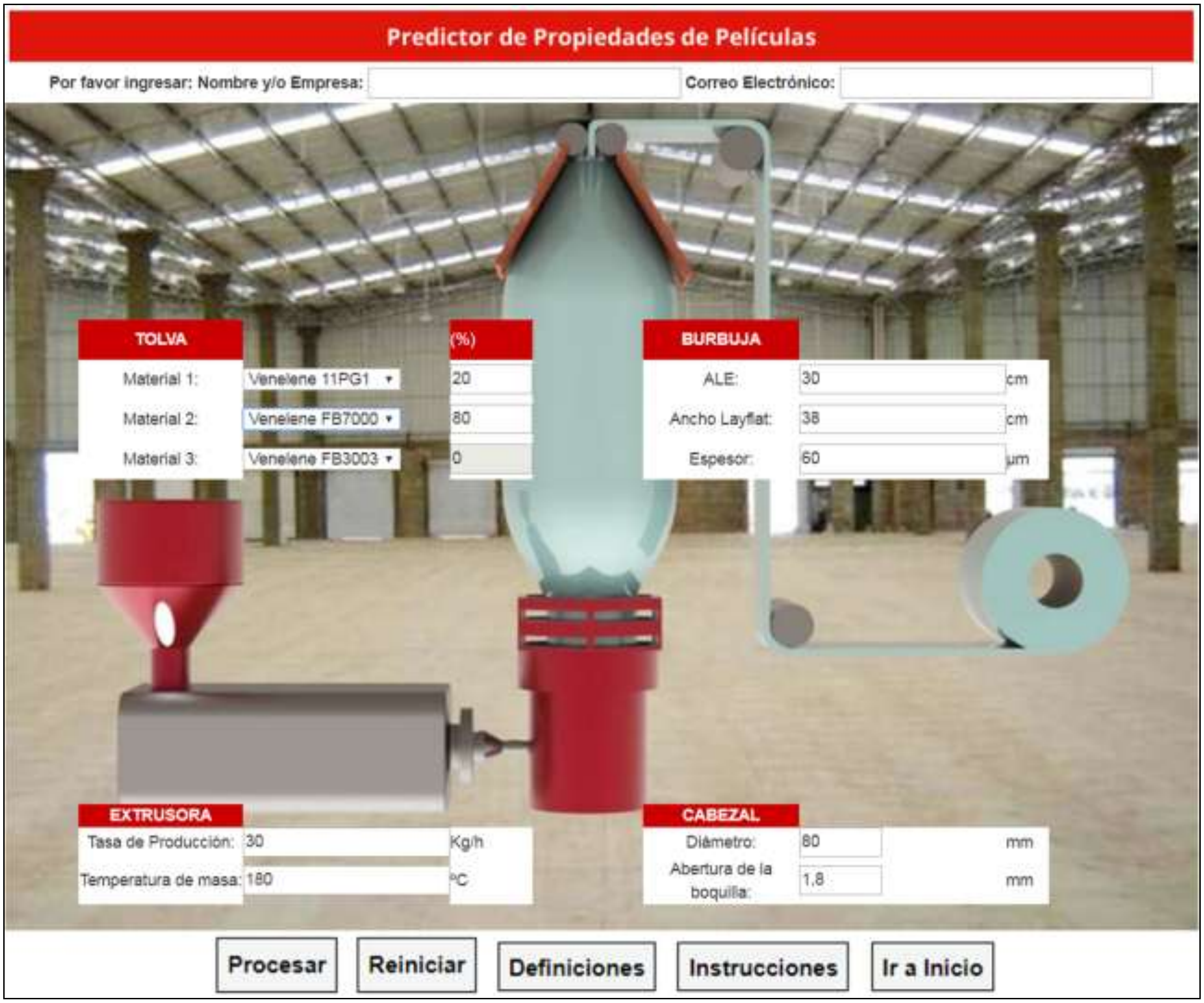

Figure 3: Page use to specify the materials and processing conditions

Once all the data are inserted correctly, "Procesar" button is selected. The system displays a screen to validate this data, where the user must press the "Procesar" button again to get the results calculated by the predictor. The film properties display by the tool are divided into two types: mechanical and barrier properties; in the first one, results of puncture resistance, tensile strength and elongation at break are found, and in the barrier properties values of water vapor and oxygen transmission rates are shown (see Figure 4).

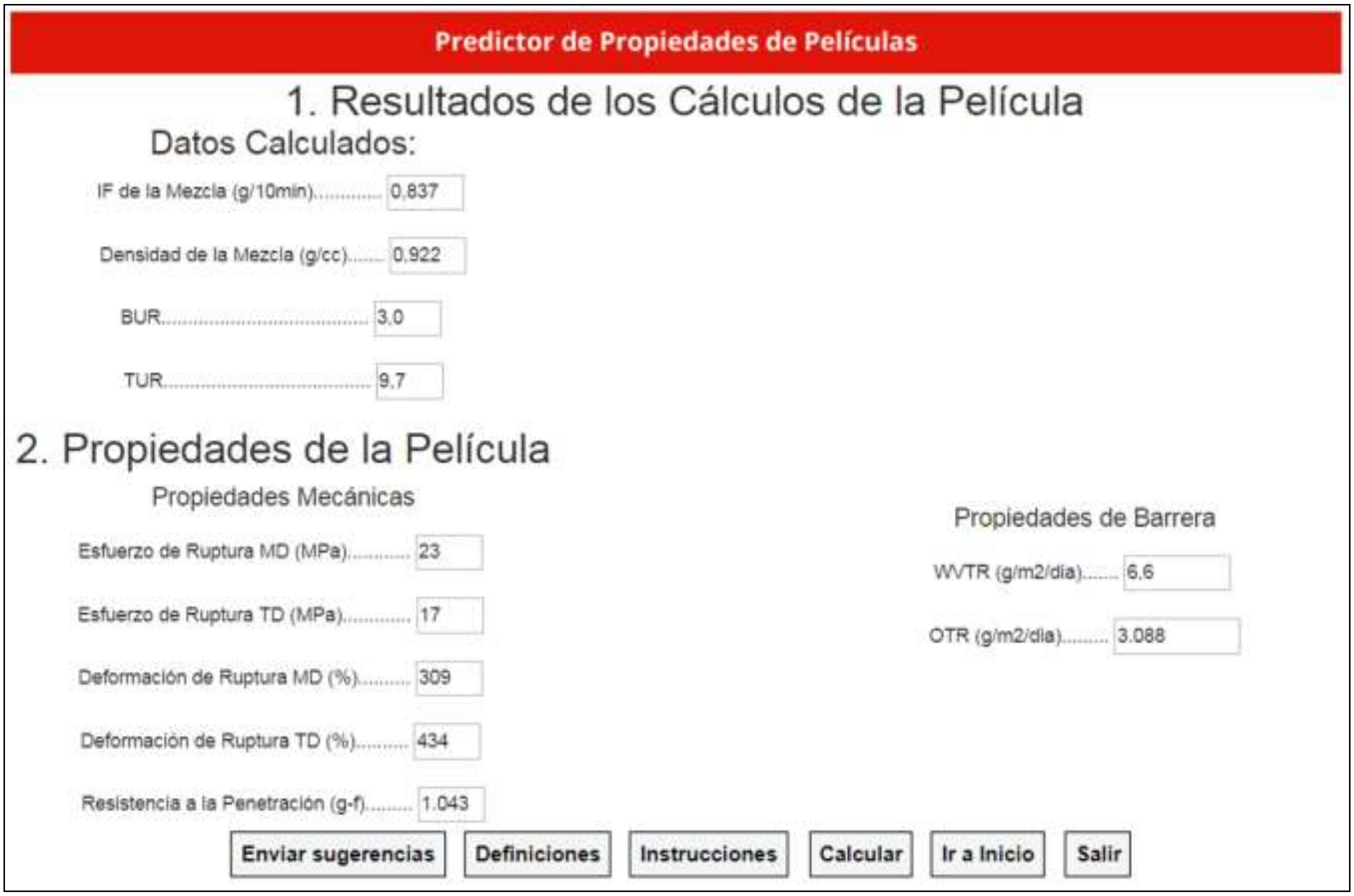

Figure 4: Results sheet

4 Example of using the Film Properties Predictor

Below it is presented a hypothetical case to illustrate the benefits of using the Film Properties Predictor.

A film manufacturer processes a blend of LDPE Venelene® FB7000 (70%) with LLDPE Venelene® 11PG1 (30%), to fabricate films used as sandbags with a thickness of 90 µm. It is used a processing temperature profile ranging from 150 to 170 °C, obtaining a melting temperature of 180 °C. The production rate is 40 kg/h and the film has a width of 47 cm. In addition, it employs an extruder that has a die head with a diameter of 80 mm and a gap of 1.8 mm, which can be replace by an 80 mm diameter die with gap of 1.2 mm, if it is needed.

This manufacturer wants to increase the tensile properties of his products because several complaints have been received from his clients caused by break failures presented during bag handling and, at the same time, he would like to decrease production costs by reducing the film thickness in a least 10%. This makes both properties (strength and elongation) and resistance essential to avoid leakage of the contained product and ensure customers' satisfaction. In this way, using the Film Predictor and employing the conditions before, the results shown in

Table 1 are obtained.

Table 1: Sandbag properties (70% FB7000 + 30% 11PG1, 90 µm)

Mechanical Properties	
Tensile Strength at break MD (MPa)	18
Tensile Strength at break TD (MPa)	24
Elongation at break MD (%)	481
Elongation at break TD (%)	595
Puncture resistance (g-f)	1,316

The first step that the manufacturer could carry out is to study the effect that a thickness reduction from 90 to 80 µm would have on film performance, without altering the formulation used to determine if it has a significant change in the final properties. Thus, using the Film Properties Predictor, the obtained results are shown in Table 2, where a reduction in three of the essential properties for the application is observed: tensile strength at break TD, elongation at break MD and puncture resistance. This result would be unsatisfactory, given that it is necessary to increase the film tensile properties without affecting puncture resistance.

Table 2: Sandbag properties (70% FB7000 + 30% 11PG1, 80 µm)

Mechanical Properties	
Tensile Strength at break MD (MPa)	19
Tensile Strength at break TD (MPa)	23
Elongation at break MD (%)	458
Elongation at break TD (%)	595
Puncture resistance (g-f)	1,237

In order to enhance the tensile properties and make possible a thickness reduction, the option under consideration is to change LLDPE proportion in the blend. In this way, taking benefit from the advantages offered by the Film Properties Predictor of making iterations without incurring in raw material waste, it is evaluated the performance of a film with 80 µm and a change in the proportions of LDPE and LLDPE used in the initial film under the same processing conditions. The observed performance (see Table 3) indicates that despite thickness reduction, by increasing the LLDPE content to 70%, it is possible to improve tensile properties of the package; however, puncture resistance is affected with respect to the initial bag with a thickness of 90 µm, so this option still does not look at all attractive.

Table 3: Sandbag properties (30% FB7000 + 70% 11PG1, 80 µm)

Mechanical Properties	
Tensile Strength at break MD (MPa)	26
Tensile Strength at break TD (MPa)	25
Elongation at break MD (%)	619
Elongation at break TD (%)	780
Puncture resistance (g-f)	1,267

To analyze alternatives that enhance the puncture resistance, it is then proposed the use of a die head with a diameter of 80 mm and a gap of 1.2 mm; this could balance molecular orientation in the film. In this way, before changing the machine die head and invest hours of hard work, this option is evaluated in the Film Properties Predictor, obtaining the results shown in Table 4. The values reached are favorable, since they allow increasing all mechanical properties of the bag with a thinner film.

Table 4: Sandbag properties (30% FB7000 + 70% 11PG1, 80 µm and die gap of 1.2 mm)

Mechanical Properties	
Tensile Strength at break MD (MPa)	32
Tensile Strength at break TD (MPa)	27
Elongation at break MD (%)	538
Elongation at break TD (%)	1,049
Puncture resistance (g-f)	1,555

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Table 5: Summary of results provided by the Film Properties Predictor

	Units	Original	Case 1	Difference	Case 2	Difference	Case 3	Difference
% of LDPE	-	70	70	-	30	-	30	-
% of LLDPE	-	30	30	-	70	-	70	-
Production rate	kg/h	40	40	-	40	-	40	-
Die diameter	mm	80	70	-	80	-	80	-
Die gap	mm	1,8	1,8	-	1,8	-	1,2	-
Thickness	µm	90	80	**-11%**	80	**-11%**	80	**-11%**
Strength at break MD	MPa	18	19	**6%**	26	**44%**	32	**78%**
Strength at break TD	MPa	24	23	**-4%**	25	**4%**	27	**13%**
Elongation at break MD	%	481	458	**-5%**	619	**29%**	538	**12%**
Elongation at break TD	%	595	595	**0%**	780	**31%**	1.049	**76%**
Puncture resistance	g	1.316	1.237	**-6%**	1.267	**-4%**	1.555	**18%**

(blue)	Indicates an advantage
(green)	Indicates that there was no advantage or disadvantage
(red)	Indicates a disadvantage

Table 5 shows the benefits of change (thinner and higher mechanical properties) that presents a new alternative found by this transformer using the Film Properties Predictor, highlighting how easy can be using this tool offered by POLINTER to all its customers for the optimization of their products.

5 Conclusions

The Film Properties Predictor allows analyzing in a fast way the effects of changes of resin, thicknesses and processing conditions on the final product properties. All these predictions enable to minimize human effort and machine resource required to optimize the films manufactured by the POLINTER clients with Venelene® products.

6 References

For further information, the next references can be consulted:

1. Torres, A., Guastaferro, F. Curso de Mezclas de Polímeros. Indesca, Venezuela, (2006)
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5. Fuenmayor, J. Predictor de Propiedades de Películas. Internal report, Indesca, Venezuela (2017).

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